

Claims

We claim:

1. A method of modeling dielectric losses in a transmission line, the method comprising:

modeling a resistance, a self-inductance, and a self-capacitance for a line as a lumped element circuit having a first port and a second port, where a signal is received on the first port; and

modeling a dielectric loss as a scattering matrix connected to the second port.

2. The method of claim 1, wherein the scattering matrix uses values based upon a low-loss condition wherein the intrinsic impedance of the line is unaffected by losses, whereby reflection coefficients for the first and second ports are defined to be zero if the scattering matrix is normalized to the intrinsic impedance.

3. The method of claim 1, wherein the scattering matrix uses values that vary with a frequency of the signal.

4. The method of claim 1, wherein the scattering matrix uses values that are related to the dielectric constant of a material in which the line is embedded.

5. The method of claim 1, further comprising calculating the resistance, inductance, and capacitance.

6. The method of claim 1, further comprising modeling a skin effect resistance and a skin effect inductance using an R-L tank circuit connected to the second port.

7. The method of claim 1, further comprising modeling the losses using circuit simulation software.

8. A method for simulating a transmission line comprising:

determining a resistance of a transmission line;

determining a self-inductance of the line;

determining a self-capacitance of the line;

creating a computer model of the line as a schematic having first and second ports;

modeling the resistance as a resistor in series with an inductor that represents the self-inductance;

modeling the self-capacitance as a capacitor connected to the line; and

modeling a dielectric loss as a scattering matrix connected to the second port, wherein the scattering matrix [S] represents conductance of the transmission lines across a broad band of frequencies.

9. The method of claim 8, further comprising modeling a signal received on the first port.

10. The method of claim 8, wherein the scattering matrix uses values that are related to the dielectric constant of a material in which the line is embedded.

11. The method of claim 8, wherein the transmission line is a line on an electronic circuit board or an integrated circuit chip.

12. The method of claim 8, wherein the line is simulated using circuit simulation software.

13. The method of claim 8, wherein the step of modeling the dielectric loss comprises using a two-by-two matrix described as:

$$[S] = \begin{bmatrix} 0 & \exp\left(-\frac{\pi f \sqrt{\epsilon_r} \tan \delta}{c} \cdot l\right) \\ \exp\left(-\frac{\pi f \sqrt{\epsilon_r} \tan \delta}{c} \cdot l\right) & 0 \end{bmatrix}.$$

14. A computer-readable medium having computer-executable instructions for performing a method for modeling transmission lines, the method comprising:

modeling a resistance, a self-inductance, and a self-capacitance for a line as a lumped element circuit having a first and second port, where a signal is received on the first port; and

modeling a dielectric loss as a scattering matrix connected to the second port.

15. The medium of claim 14, wherein the scattering matrix uses values based upon a low-loss condition wherein the intrinsic impedance of the line is unaffected by losses, whereby reflection coefficients for the first and second ports are defined to be zero if the scattering matrix is normalized to the intrinsic impedance.

16. The medium of claim 14, wherein the scattering matrix uses values that vary with a frequency of the signal.

17. The medium of claim 14, wherein the scattering matrix uses values that are related to the dielectric constant of a material in which the line is embedded.

18. The medium of claim 14, wherein the method further comprises calculating the resistance, inductance, and capacitance, and wherein the steps of modeling comprise using circuit simulation software.

19. The medium of claim 14, wherein the method further comprises modeling a skin effect resistance and a skin effect inductance using an R-L tank circuit connected to the second port.

20. The medium of claim 14, wherein the step of modeling the dielectric loss comprises using a two-by-two matrix described as:

$$[S] = \begin{bmatrix} 0 & \exp\left(-\frac{\pi f \sqrt{\epsilon_r} \tan \delta}{c} \cdot l\right) \\ \exp\left(-\frac{\pi f \sqrt{\epsilon_r} \tan \delta}{c} \cdot l\right) & 0 \end{bmatrix}.$$